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THREE DIMENSIONAL DISPLAY

Abstract:

Abstract of WO9115930

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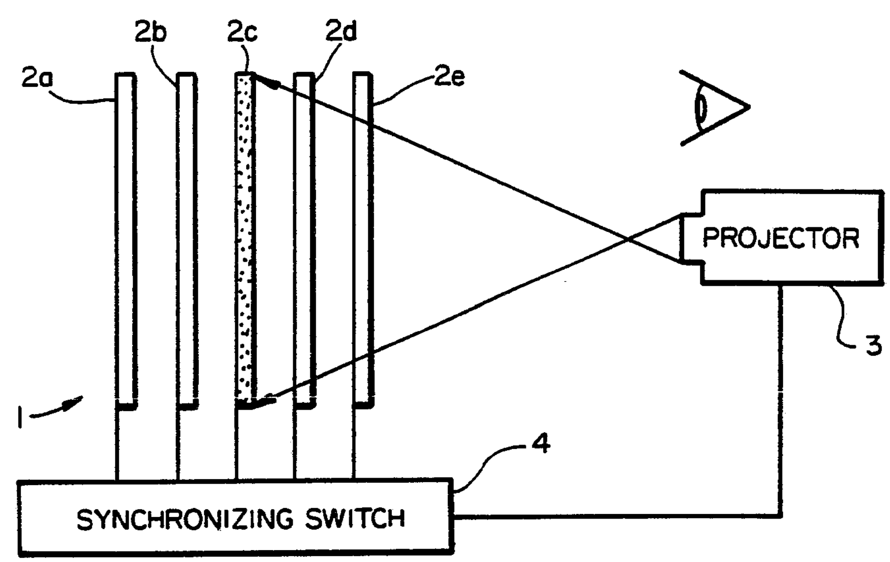

(57) Abstract

A three dimensional display comprises (a) a plurality of switchable screens (2a-e) arranged one behind the other, each screen being independently switchable between a strongly scattering and substantially transparent state; (b) projection means (3) for projecting a sequence of images, each image in the sequence corresponding to one of the switchable screens and forming part of an overall three-dimensional image; and (c) synchronized switching means (4) for switching each switchable screen synchronously with the projection of the sequence of images by the projection means, such that a particular switchable screen is in its strongly scattering state when image corresponding thereto is being projected and is in its substantially transparent state at least when the image corresponding to another screen is being projected and the particular screen is positioned between that another screen and either the projector or the viewer.

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Three Dimensional Display

Background of the Invention

This invention relates to three dimensional displays, in particular three dimensional displays having enhanced contrast.

A number of three dimensional displays are known. Some can present only static images, that is images which do not change. Others are dynamic, that is, they can present moving images. However, many prior art displays are cumbersome, requiring complex bulky and/or complex equipment.

The present invention provides a simple dynamic three dimensional display.

Summary of the Invention

A three dimensional display of my invention comprises:

(a) a plurality of switchable screens arranged one behind the other, each screen being independently switchable between a strongly scattering and substantially transparent state;

(b) projection means for projecting a sequence of images, each image in the sequence corresponding to one of the switchable screens and forming part of an overall three-dimensional image; and

(c) synchronized switching means for switching each switchable screen synchronously with the projection of the sequence of images by the projection means, such that a particular switchable screen is in its strongly scattering state when image corresponding thereto is being projected and is in its substantially transparent state at least when the image corresponding to another screen is being projected and the particular screen is positioned between that another screen and either the projector or the viewer.

Brief Description of the Drawing(s)

Figures 1a and 1b show a front projection display of this invention.

Figures 2a and 2b show a front projection display of this invention having a dark background screen for enhanced contrast.

Figures 3a and 3b show a rear projection display of this invention.

Figures 4 and 5 show schematically single and multiple projector arrangements, respectively, for displays of my invention.

Description of the Preferred Embodiments

In the display of this invention a three-dimensional effect is achieved by sequentially projecting portions of an overall three dimensional image. Each portion is projected onto a different screen, the screens being arranged one behind the other. Each screen is independently switchable between a substantially transparent state and a strongly scattering state. When the image corresponding thereto is being projected, a screen is in its strongly scattering state. When the image corresponding to another screen is being projected, the screen is switched to its substantially transparent state, to permit light from the projector to reach that another screen, or to permit the viewer to see the image formed on that another screen, or both.

In order to present a realistic three dimensional image, the eye has to fuse the individual images together. This can be achieved if the total sequence of images is shown at a repetition rate greater than the critical flicker frequency, generally between 50 and 70 Hz, depending on the picture size and brightness.

Referring now to the Figures (where like numerals designated like parts), Figures 1a and 1b show a front projection display 1 of this invention. Switchable screens 2a-2e are arranged one in front of the other. In Figure 1a, projection means 3 is shown projecting onto screen 2c, which is in its

strongly scattering state. To permit light from projection means 3 to reach screen 2c, screens 2d and 2e have been switched by synchronizing switch 4 into their transparent state. The state of screens 2a and 2b is immaterial, since no light from projection means 3 needs to pass through them or is being projected on them at the moment shown, although as a matter of convenience in designing the synchronizer circuitry, it may be simpler to have them switched to the transparent state whenever an image is not being projected onto them. In Figure 1b, projection means 3 is now projecting onto screen 2b, and synchronizing switch 4 has accordingly switched screen 2b to its scattering state (if it was not in that state already) and switched screen 2c to its transparent state to permit light from projection means 3 to reach screen 2b. It is preferred that each of screens 2a-2e, when in its strongly light scattering state, scatter at least 90% of a beam of light collimated to within 5° impinging thereon outside of a 5° cone. Conversely, it is preferred that each screen, when in its substantially transparent state, transmit at least 80% of the light impinging thereon. The overall three dimensional image is formed by the projection of a sequence of images on screens 2a-2e, with the switching between the various screens being sufficiently fast so that the human eye perceives not each image individually, but the aggregate three-dimensional image. It is to be understood that although in the Figures a five-screen arrangement is shown, this number is only illustrative. The three dimensional displays of this invention can be made with a greater or lesser number of switchable screens, according to the degree of three dimensional effect desired.

Figures 2a and 2b show another front projection display, having enhanced contrast. The display of these Figures differs from the display of Figures 1a-b in having a dark, light absorbing background screen 5 behind the switchable screens 2a-e. As before, projection means 3 projects a three-dimensional image portion-wise, one image for each depth plane of the overall image. However, projection means 3 has a duty cycle of less than 1:1 — that is, it is not projecting all the time. There is an interval between the projection of consecutive image portions, during which the projector is dark. During such intervals, synchronizing switch 4 switches all of screens 2a-2e to their transparent states, so that the viewer sees all the way through them to dark background screen 5. In this manner, the viewer sees a high

contrast display comprising bright image (when projection means 3 is projecting) against a dark background (when projection means 3 is not projecting). Typical duty cycles are about 1:10, and preferably are in the range between about 1:5 and about 1:200.

The synchronized switching of screens to achieve higher contrast is also described in US patent application no. 07/505,206; filed 5 April 1990, the disclosure of which is incorporated herein by reference.

Figures 3a and 3b show schematically a rear projection display 10 of this invention. The display operates similarly to that shown in Figures 1a-b, except that synchronizing switch 4 switches all the screens onto which an image is not being projected to their transparent state, so that light can either pass through them to the viewer (screens 2a and 2b in Figure 3a) or through them from the projection means to the screen onto which the image is being projected (screens 2d and 2e in Figure 3a).

The projection means can be either a single projector projecting the various images in sequence, or can be an array of plural projectors operating in combination. For a low number of screens, for example 3 or 4, a single projector such as a cathode ray tube (CRT) projector can be used, running at a field frequency of 180 Hz. Figure 4 shows schematically a circuit arrangement with a single projector.

Generally, the larger the number of image plances, the more realistic the three-dimensional impression perceived by the viewer. With a large number of image planes, it may be desirable to use 35 mm slide projectors, with one projector per plane, for stationary three dimensional images. For moving three-dimensional images, multiple liquid crystal projectors, each handling at least one image plane, can be used. In this case, the light output from the projectors could be pulsed in synchronization with the individual plane screens, thus keeping the field rate requirements on the projector low. Figure 5 shows schematically a multiple projector arrangement.

In each of the arrangements of Figures 4 and 5, each three dimensional image plane has a field synchronication signal associated with it, that signals the start of a new field. This signal is fed to a counter which, with the aid of a multiplexer, selects the drive to the appropriate screen and/or projector.

Preferably the switchable screens in the displays of this invention comprise an encapsulated liquid crystal material, whose preparation is disclosed in U.S. Pat. Nos. 4,435,047 (1984), 4,606,611 (1986), 4,616,903 (1986), and 4,707,080 (1987), all to Fergason; published European patent application EP 156,615 (1985), by Pearlman et al.; U.S. Pat. No. 4,671,618 (1987), to Wu et al.; U.S. Pat. Nos. 4,673,255 (1987) and 4,685,771 (1987), to West et al.; and U.S. Pat. No. 4,688,900 (1987) to Doane et al.; the disclosures of each which are incorporated herein by reference. In encapsulated liquid crystal material, discrete volumes of liquid crystals are encapsulated, dispersed, embedded or otherwise contained in a containment medium. "Liquid crystals" denotes a composition having liquid crystalline properties, whether that composition is a single discrete liquid crystalline compound, a mixture of of different liquid crystalline compounds, or a mixture of liquid crystalline and non-liquid crystalline compounds.

Liquid crystals have typically elongated molecular shapes, with a tendency to align or orient themselves with their long molecular axes parallel to each other. This alignment causes liquid crystals to be anisotropic, meaning that their measured physical, optical, and other properties are dependent on the direction of measurement (parallel or perpendicular to the direction of alignment). Further, the alignment direction can be influenced by an external stimulus, such as an electrical or magnetic field, causing the liquid crystals to exhibit a particular value of a physical characteristic in one direction when the stimulus is absent, but rapidly switching to a different value when the stimulus is applied. It is because of their anisotropy and their ready realignment that liquid crystals are useful as materials for displays.

The containment medium is preferably a polymeric material. Suitable containment media include but are not limited to poly(vinyl

alcohol), polyurethane, acrylic and methacrylic polymers and copolymers, epoxies,polyolefins, vinyl polymers, and the like.

Encapsulated liquid crystal material can be formed by deposition from an emulsion containing both the containment medium and liquid crystals or by the evaporation of liquid from a solution containing both containment medium and liquid crystals. It can also be formed by making an initially homogeneous mixture containing both containment medium and liquid crystals at an elevated temperature, then cooling to phase-separate out liquid crystal volumes contained in the containment medium. Further, it can be formed by an in-situ polymerization process, in which the containment medium is polymerized and simultaneously encapsulates liquid crystal material. The liquid crystal need not be entirely surrounded by the polymer, and may exist as part of a system with co-continuous phases.

In one embodiment, the encapsulated liquid crystal material is substantially non-transparent in the absence of a sufficient electric field (the "field-off" state) and substantially transparent in the presence of a sufficient electric field (or "field-on" state). The electric field induces a change in the alignment of the liquid crystals, in turn causing the encapsulated liquid crystal material to switch from a highly light-scattering (and/or absorbent) state to a highly non-scattering and substantially transparent state. Generally, it is preferred that the liquid crystals have a positive dielectric anisotropy and that the ordinary index of refraction of the liquid crystals be matched with the refractive index of the containment medium, while the extraordinary index of refraction is substantially mismatched therewith. The physical principles by which such encapsulated liquid crystal material operates is described in further detail in the aforementioned references, particularly the patents to Fergason. Thus, a screen or shutter made of encapsulated liquid crystal material can be made to switch from a light scattering state to a substantially transparent state by the application of an electric field.

The means for applying the electric field may be various. Generally, the liquid crystal material has an electrically conductive material or

electrode on either side. The application of a sufficient voltage across the two electrodes then induces a corresponding change in the visual appearance of the liquid crystal material between the electrodes. Typically, the transparent electrode material comprises a thin coating of a metal or metal oxide, such as gold, nickel, indium tin oxide, and the like.

Claims

I claim:

1. A three dimensional display, comprising:
   (a) a plurality of switchable screens arranged one behind the other, each screen being independently switchable between a strongly scattering and substantially transparent state;
   (b) projection means for projecting a sequence of images, each image in the sequence corresponding to one of the switchable screens and forming part of an overall three-dimensional image; and
   (c) synchronized switching means for switching each switchable screen synchronously with the projection of the sequence of images by the projection means, such that a particular switchable screen is in its strongly scattering state when image corresponding thereto is being projected and is in its substantially transparent state at least when the image corresponding to another screen is being projected and the particular screen is positioned between that another screen and either the projector or the viewer.

2. A three dimensional display according to claim 1, wherein each of the switchable screens comprises encapsulated liquid crystal material.

3. A three dimensional display according to claim 1 or claim 2, wherein the synchronized switching means switches each of the switchable screens to its substantially transparent state when an image is not being projected thereon by the projecting means.

4. A three dimensional display according to claim 3, further comprising a dark, light absorbing background screen positioned behind the switchable screen which is furthermost from the projecting means.

5. A three dimensional display according to claim 1 or claim 2, wherein the projecting means comprises a single projector.

6. A three dimensional display according to claim 1 or claim 2, wherein the projecting means comprises a plurality of projectors, each projector being associated with a different screen.

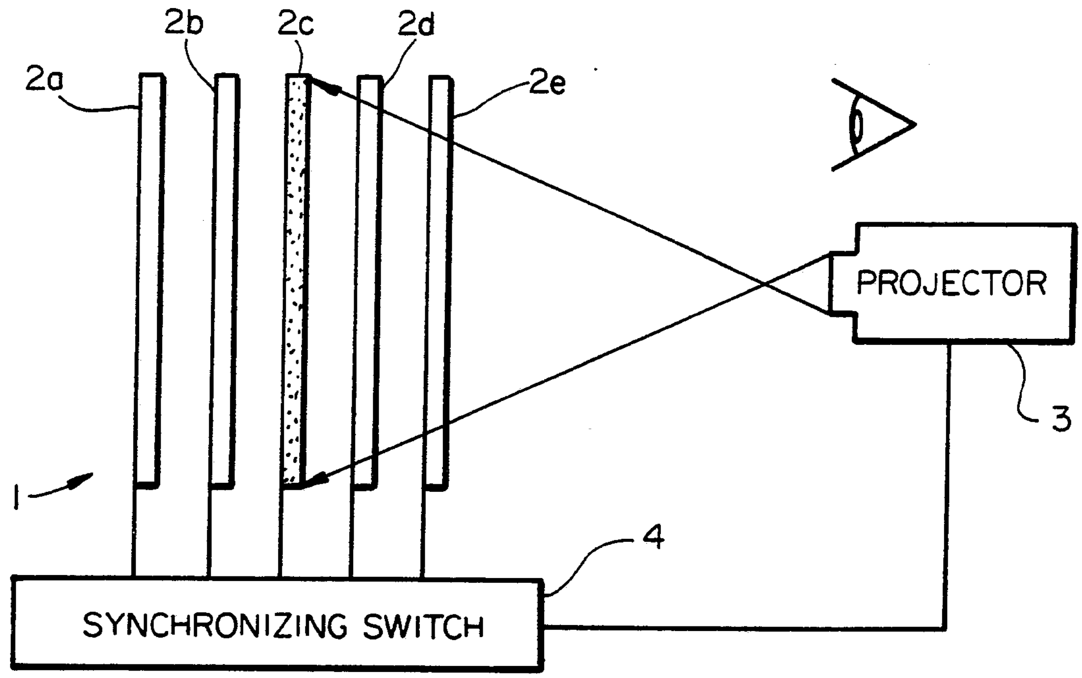
2a
2b
2c
2d
2e
PROJECTOR
3
1
4
SYNCHRONIZING SWITCH

FIG_1a

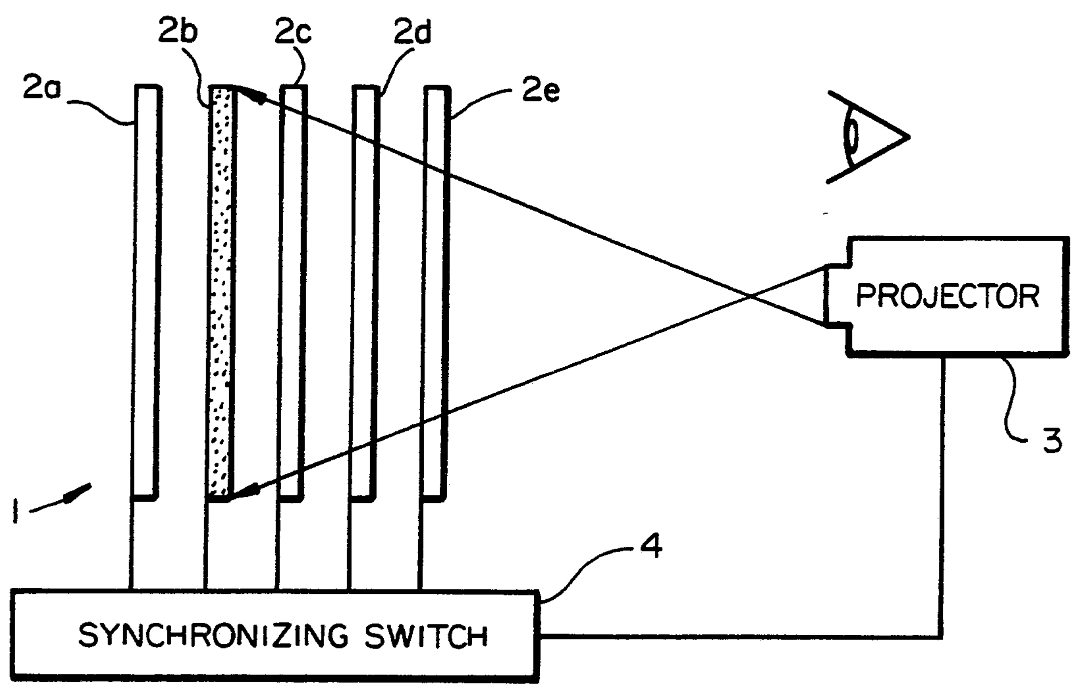
2a
2b
2c
2d
2e
PROJECTOR
3
1
4
SYNCHRONIZING SWITCH

FIG_1b

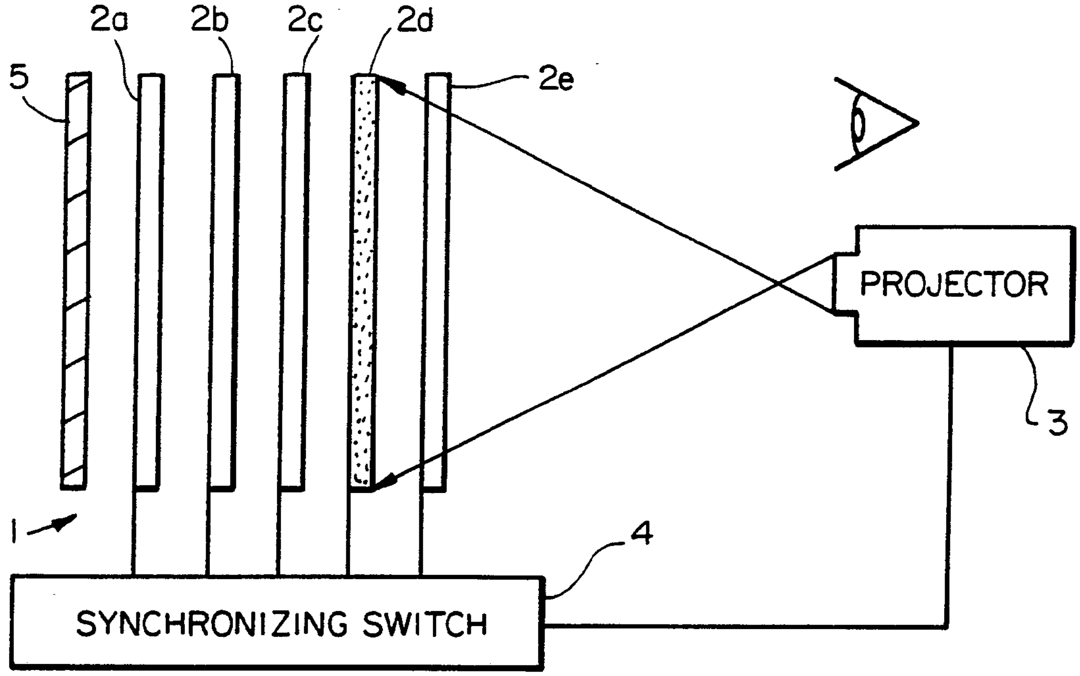
2a
2b
2c
2d
5
2e
PROJECTOR
3
1
4
SYNCHRONIZING SWITCH

FIG_2a

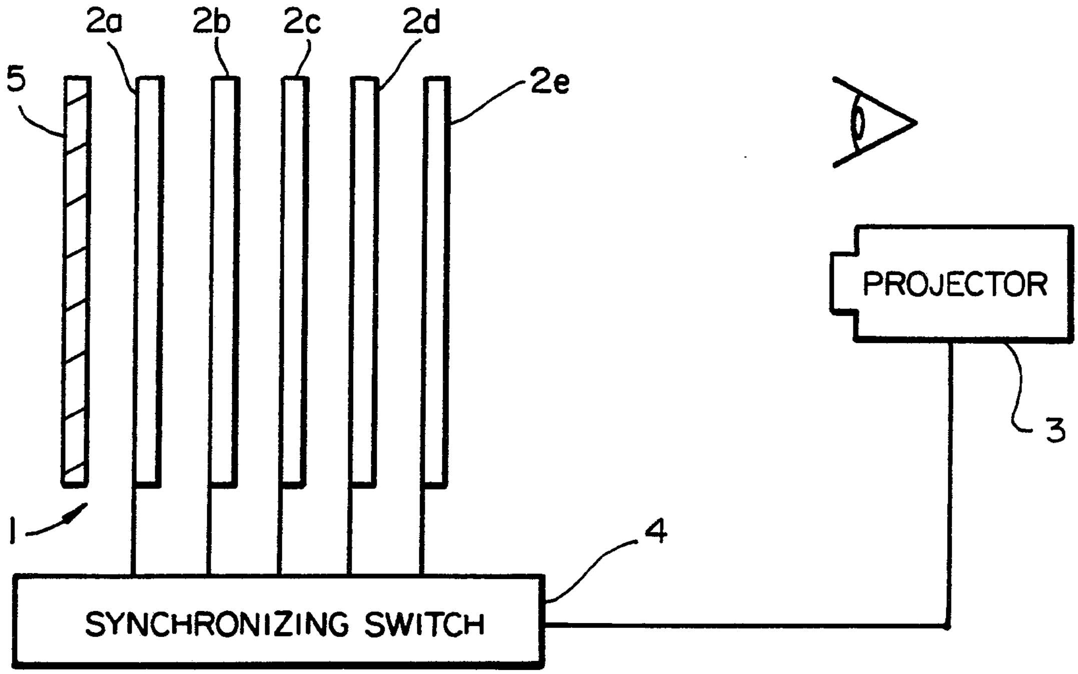
2a
2b
2c
2d
5
2e
PROJECTOR
3
1
4
SYNCHRONIZING SWITCH

FIG_2b

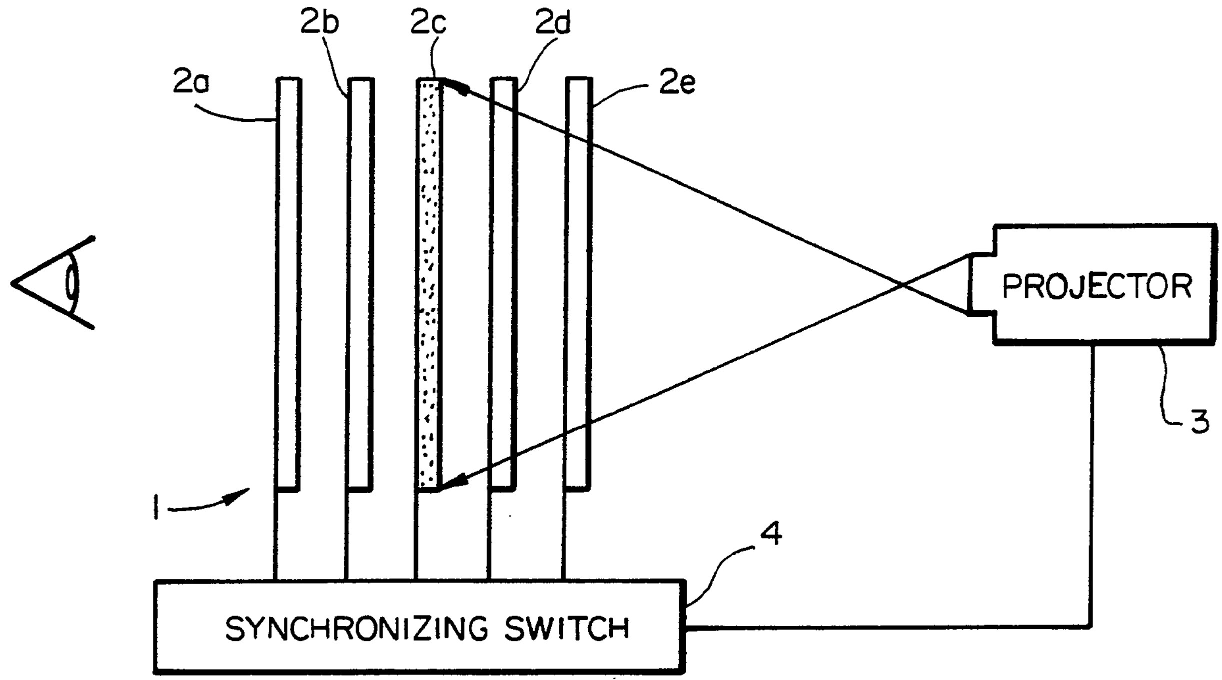
2a
2b
2c
2d
2e
PROJECTOR
3
1
4
SYNCHRONIZING SWITCH

FIG_3a

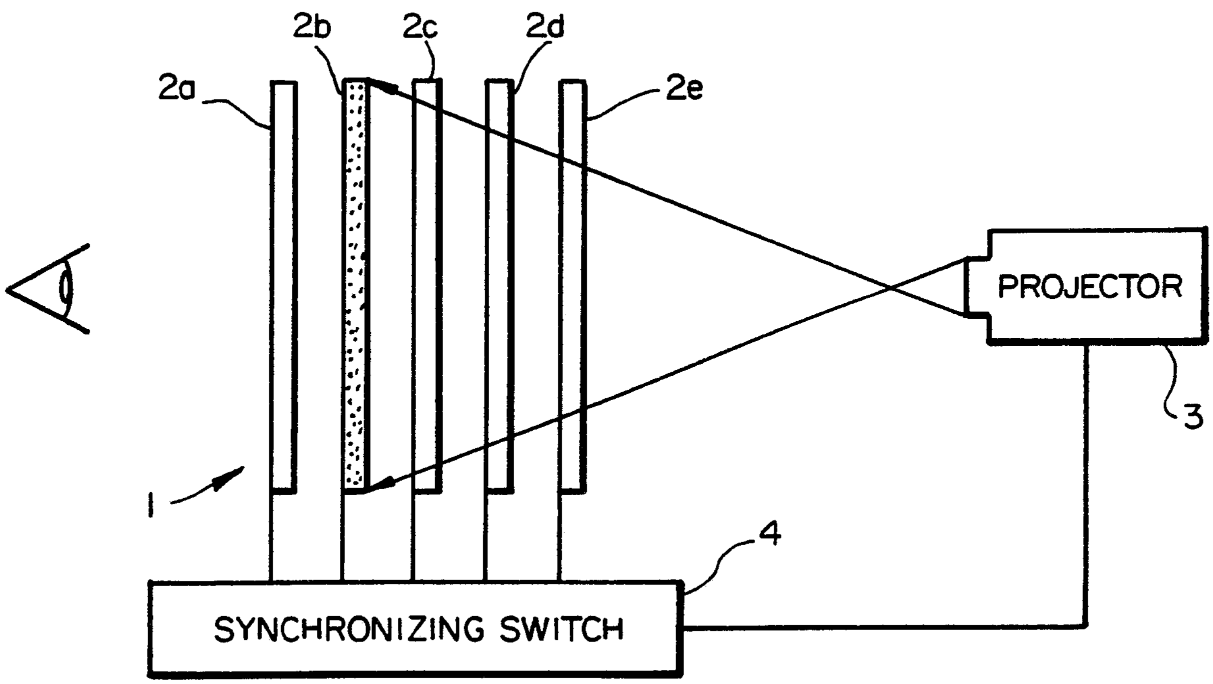
2a
2b
2c
2d
2e
PROJECTOR
3
1
4
SYNCHRONIZING SWITCH

FIG_3b

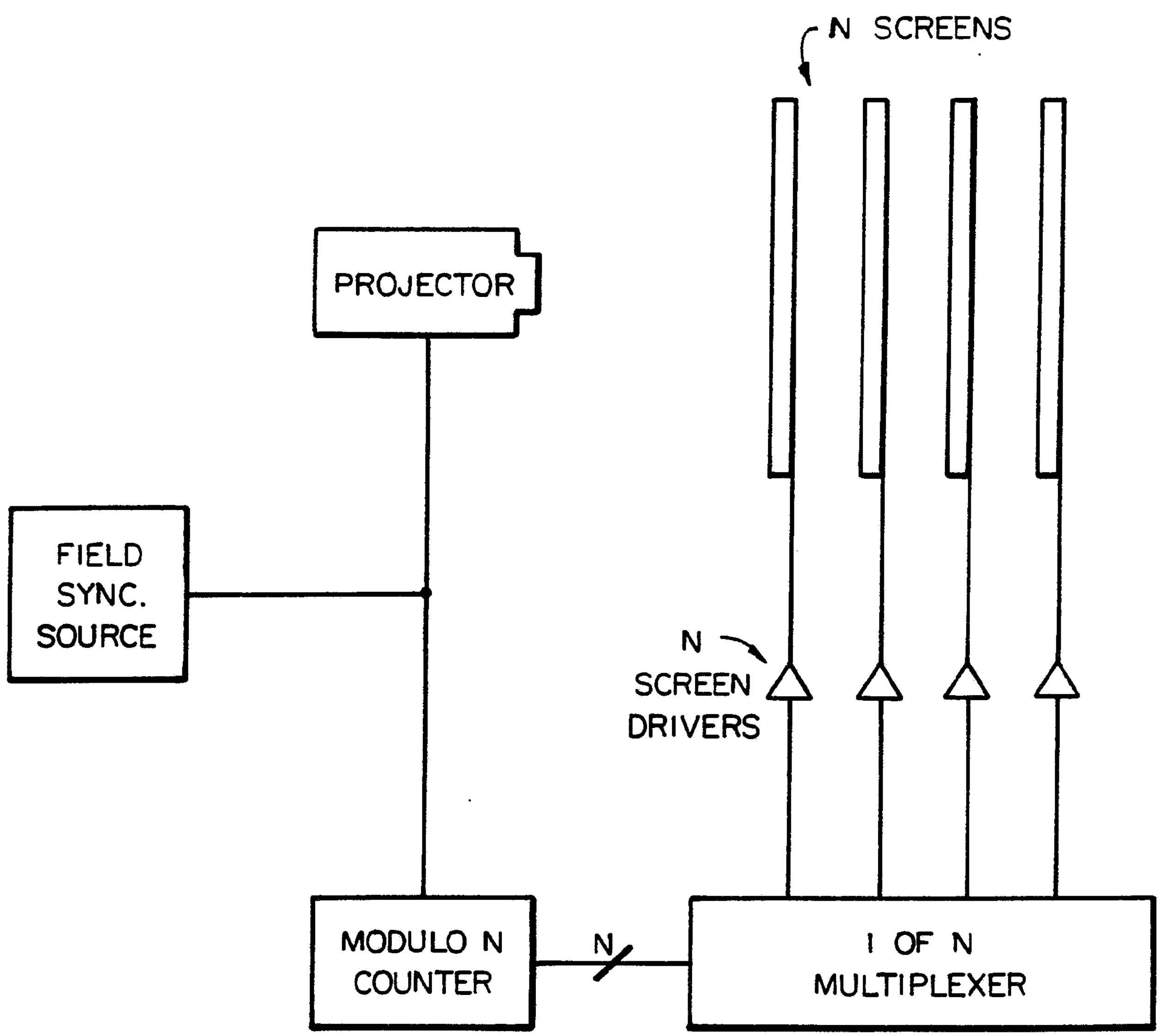
N SCREENS
PROJECTOR
FIELD SYNC. SOURCE
N SCREEN DRIVERS
MODULO N COUNTER
N
1 OF N MULTIPLEXER

FIG_4

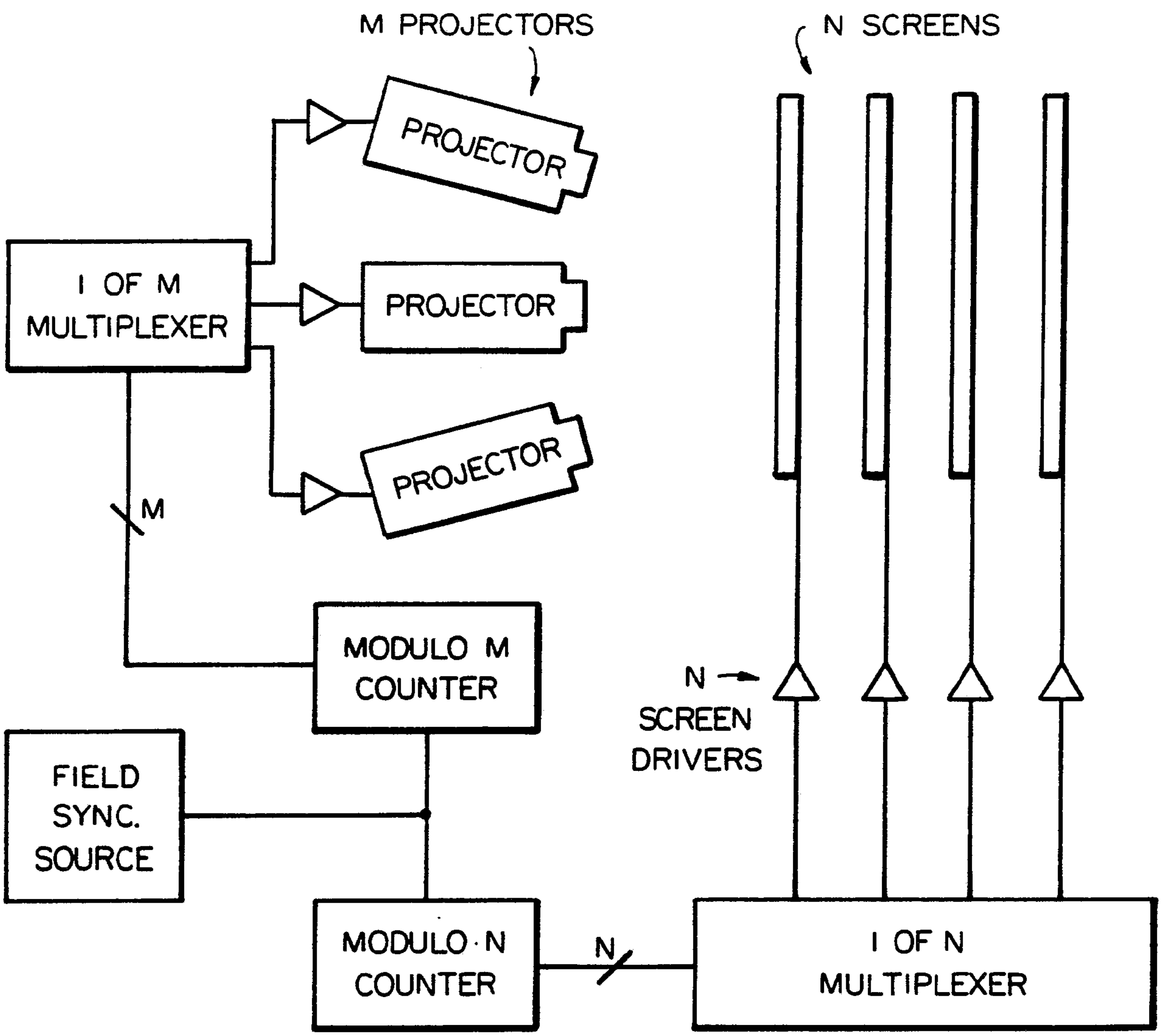
M PROJECTORS
N SCREENS
PROJECTOR
PROJECTOR
PROJECTOR
1 OF M
MULTIPLEXER
M
MODULO M
COUNTER
FIELD
SYNC.
SOURCE
MODULO N
COUNTER
N
N
SCREEN
DRIVERS
1 OF N
MULTIPLEXER

FIG_5